A Study of the Effect of Temperature on Dissociation and on the Temperature Coefficients of Conductivity in Aqueous Solutions.

DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY WITH THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

BY

AUGUSTUS PRICE WEST.

BALTIMORE,
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A Study of the Effect of Temperature on Dissociation and on the Temperature Coefficients of Conductivity in Aqueous Solutions.

INTRODUCTION.

It is now generally recognized that ions are the chief agents which bring about chemical action. The chemical activity of solutions is, then, a function of the dissociation of the dissolved substances. Since conductivity is a measure of dissociation, there is, therefore, a close relation between the conductivity of solutions and their chemical activity. The conductivities of a large number of substances in aqueous solutions have been determined at 18° and 25°, while at other temperatures not very much work has been done. It is well known, however, that the conductivity of solutions is greatly affected by temperature. Consequently, a study of the exact effect of temperature on the conductivity of aqueous solutions and on their dissociation, is of considerable importance, especially for those temperatures and dilutions more frequently employed in the determination of conductivity. The temperatures in question range from 0° to 35° and the dilutions from N/2 to N/1024.

Historical Review.

Quite a number of investigators have studied the effect of temperature on conductivity and some interesting results have been obtained, not only at intermediate temperatures, but at those below 0° and above 100°. It was very early observed that conductivity is affected by temperature. Ohm[1] noticed this fact in 1844 and two years later Hankel[2] made the same observation. The problem was not seriously considered, however, until some years afterwards, when Grotrian[3] took it up.

[1] Pogg. Ann., **63**, 403 (1844).
[2] *Ibid.*, **69**, 255 (1846).
[3] *Ibid.*, **151**, 378 (1874).

He determined the conductivity of a few dilutions of sulphuric and hydrochloric acids, at various temperatures, and showed that the effect of temperature on conductivity, in the case of sulphuric acid, could be represented by an equation of the form

$$L_t = L_0 (1 + \alpha t + \beta t^2),$$

and in the case of hydrochloric acid the temperature effect could be represented by the formula

$$L_t = L_0 (1 + \alpha t).$$

In each of these formulas L_t represents the molecular conductivity, t is the temperature in question, and α and β are constants.

Kohlrausch and Grotrian,[1] a year later, studied the influence of temperature on conductivity. They worked out the temperature coefficients of a few acids and salts, and suggested that the effect of temperature on conductivity could be best represented by the formula which Grotrian had deduced for sulphuric acid.

Other investigators have determined temperature coefficients of conductivity but, in many cases, they studied only a few compounds at various dilutions.

Krannhals[2] determined the conductivity of hydrochloric acid and a few inorganic salts, over a range of temperature extending from 18° to 100°. He found, as others before him had done, that conductivity increases with rise in temperature and with increase in dilution. He concluded from his results that temperature has no effect on dissociation. Rudolphi[3] made some conductivity measurements between 25° and 100°. His results also showed that temperature has practically no effect on dissociation. Jahn[4] determined the conductivity of a number of fatty acids between 10° aad 50°. He measured dilutions only as high as N/128, consequently, his dissociation values could not be very accurate. Others who have made conductivity measurements at different temperatures and cal-

[1] Pogg. Ann., **154**, 224 (1875).
[2] Z. physik. Chem., **5**, 250 (1890).
[3] *Ibid.*, **17**, 385 (1895).
[4] *Ibid.*, **16**, 72 (1895).

culated temperature coefficients, are Bouty,[1] Long[2] and Freund.[3]

Arrhenius,[4] in 1887, showed the connection between the lowering of the freezing-point of a solvent by an electrolyte and the conductivity of the electrolyte. In most of the earlier experiments, however, the values obtained for the amount of dissociation at 0°, by the freezing-point method, were generally a little higher than those obtained by the conductivity method at 18° and 25°. This would indicate that there is a small negative temperature coefficient of dissociation. Two years later Arrhenius[5] studied this problem. He worked out the temperature coefficients of conductivity of a number of salts, at various temperatures, ranging from 18° to 52°. His results showed that temperature has little or no effect on dissociation.

Déguisne[6] studied the effect of temperature on conductivity in very dilute, or completely dissociated solutions of strong electrolytes. He worked at various temperatures from 0° to 34° and expressed the influence of temperature, t, on the conductivity, K, starting from 18° as a mean temperature, in the form of the following equation :

$$Kt = K_{18}\,(1 + \alpha(t-18) + \beta(t-18)^2).$$

R. W. Wood[7] measured the conductivity of several electrolytes in dilute solutions, at 0°. He calculated the dissociation at 0° and compared his values with those obtained by Kohlrausch at 18°. He found, as others had done before him, that in dilute solutions temperature has practically no effect on dissociation.

Schaller[8] made conductivity measurements of several electrolytes in dilute solutions, at various temperatures between 25° and 100°. In order to avoid the action of water on glass

[1] Ann. Chim. Phys., [6], **3**, 498 (1884).
[2] Wied. Ann., **11**, 37 (1880).
[3] *Ibid.*, **7**, 47 (1879).
[4] Z. physik. Chem., **1**, 631 (1887).
[5] *Ibid.*, **4**, 96 (1889).
[6] Dissertation, Strassburg (1895).
[7] Phil. Mag., **41**, 117 (1896).
[8] Z. physik. Chem., **25**, 497 (1898).

at high temperatures, he employed a platinum vessel, but it was found that in the case of acids and neutral salts, vessels made of Jena glass might be used. The conductivity was found to increase with rise in temperature, but at a diminishing rate. The dissociation was found to decrease with rise in temperature. Schaller, however, did not work at temperatures as low as 0°, so that the exact effect of temperature on dissociation, for temperatures ranging from 0° to 25°, was still an unsettled question.

Whetham[1] carried out a very careful piece of conductivity work at 0°, for the purpose of comparing the dissociation values thus obtained, with those worked out by the freezing-point method a little below 0° and also with the values obtained by Kohlrausch at 18°, using the conductivity method. He worked with several electrolytes and found that dissociation decreased very slightly with rise in temperature.

Douglas[2] studied the effect of temperature on the conductivity of a number of electrolytes. He worked with several acids, bases and salts at various temperatures, ranging from 0°–35°. His results indicate that temperature has practically no effect on dissociation.

As we have seen, Whetham's results obtained the year before indicated that there was a very slight decrease in dissociation with rise in temperature. Thus the problem as to the exact effect of temperature on dissociation, over a range of temperature extending, say, from 0°–35°, was still an unsettled one. Some important investigations have been carried out at temperatures below 0° and above 35°, and some interesting results have been obtained.

Kohlrausch[3] pointed out that it was probable that the conductivities of all aqueous solutions approach, with decreasing temperature, a zero value at about the same temperature, which is —38°.5, and that the cause of this phenomenon is to be sought for in the disappearance of the fluidity of water at this temperature. In a later paper, Kohlrausch[4] showed that,

[1] Phil. Trans., **194**, 321 (1900).
[2] Am. Chem. J., **26**, 428 (1901).
[3] Sitzun. Berlin, 1028 (1901).
[4] P. Roy. Soc., **71**, 338 (1903).

if the conductivity curves of a number of electrolytes were extrapolated below 0°, in accordance with Déguisne's formula, they would all approach a zero value of conductivity at about —38°.5. He also pointed out the fact that, if the curves showing the relations between fluidity and temperature were extrapolated, they would also cut the zero axis at about the same point. That is, conductivity and fluidity disappear at the same point. Of course, wide extrapolation is necessary, and this fact must be taken into account. What is more significant, the conductivity curve for certain salts, notably sodium valerate, is almost identical with the fluidity curve, and further, the temperature coefficient of ionic mobility, in the case of slow moving ions, is almost the same as that of fluidity. In order to explain these facts and avoid the assumption that ionic motion is independent of the motion of the solvent, Kohlrausch proposed the hypothesis that about every ion there moves an atmosphere of the solvent, the dimensions of which are determined by the individual characteristics of the ion. The direct action between the ion and the solvent diminishes as the atmosphere becomes of greater dimensions. This hypothesis accounts for the apparent disappearance of fluidity and conductivity at the same temperature. The idea of ionic hydration was not entirely original with Kohlrausch. Ciamician,[1] some years before, had suggested that around every ion there is a shell of water. He also attempted, by diffusion methods, to measure the amount of this hydration.

Kunz,[2] at the suggestion of Kohlrausch, made some conductivity measurements on sulphuric acid at various temperatures, ranging from 0° to —70°. He worked with several solutions of various concentrations, from 19.1 to 63.76 per cent. His conductivity curves, representing conductivity as a function of temperature, do not meet the temperature axis at —38°.5, as Kohlrausch had predicted. Instead of the curves converging at one point, they approach the abscissa more and more slowly as the temperature falls. Kunz adopted the view that electrical resistance is due to friction. In a later article,

[1] Z. physik. Chem., **6**, 403 (1890).
[2] Compt. rend., **135**, 788 (1902).

Kunz[1] stated that he had obtained similar results with calcium chloride and sodium hydroxide. These results would seem to indicate that the hypothesis of Kohlrausch could not easily be demonstrated experimentally.

In an interesting article, W. R. Bousfield and T. M. Lowry[2] point out the effect of temperature on conductivity over a wide range of temperature. They show that conductivity-temperature curves cannot be represented by a linear or parabolic formula, as Kohlrausch has suggested. At high and low temperatures, no general formula will account for the facts. The conductivity-temperature curves, when plotted for a long range of temperature, are all inflected curves which contain a maximum point.

At low temperatures, the effect of temperature on conductivity is determined mainly by the changing mobility of the ions. At higher temperatures, the change in dissociation becomes a dominant factor and, just as the increasing viscosity of the solution leads at lower temperatures to a lower conductivity zero, at which the viscosity of the liquid would altogether prevent ionic mobility, so at higher temperatures an upper limit may exist, at which the conductivity would again become zero, owing to the complete disappearance of dissociation. The different behavior of acids and salts, which is unimportant in the case of the lower conductivity zero, becomes a vital factor in discussing the possible existence of an upper conductivity zero.

Armstrong[3] called attention to the fact that, while the majority of salts are conductors, *per se*, the acids are, in the pure state, dielectrics and only become electrolytes by interaction with a dissociating solvent. In virtue of their inherent power of self-ionization, the salts may, therefore, exhibit some conducting power, independent of that due to the dissociating properties of the solvent, while it is to be expected that the acids would cease to be electrolytes if the solvent, by reason of increasing temperature, should lose its power of dissociation.

[1] Z. physik. Chem., **42**, 591 (1903).
[2] P. Roy. Soc., **51**, 467 (1902).
[3] *Ibid.*, **40**, 268 (1886).

For this reason, evidence of the existence of an upper conductivity zero is to be looked for, in solutions of substances which, like the acids, are incapable of self-ionization.

Arrhenius[1] pointed out the effect of decreasing dissociation with rise in temperature, in the case of phosphoric and hypophosphoric acids, which exhibit maxima of conductivity at 54° and 75°, respectively. Sach[2] also observed this phenomenon in the case of aqueous solutions of copper sulphate. In the majority of cases the maximum of conductivity lies above the boiling-point, and experimental work is rendered very difficult, owing to the ready solubility of glass at high temperatures.

Miss Maltby[3] found that, on heating up to 237°, the conductivity of an aqueous solution of potassium chloride reached a maximum and decreased as the temperature rose. Hagenbach[4] observed a maximum in the conductivity of a 0.01 N solution of potassium chloride. In these experiments the conductivity cells were of glass, consequently the results were not very accurate. Noyes and Coolidge[5] studied the effect of temperature on the conductivity of aqueous solutions of sodium and potassium chlorides. They worked at various temperatures ranging from 140° to 306°. At 280° the conductivity curves of both chlorides for 0.1 N solutions reach a maximum and then fall. They proved, in the case of a 0.5 N solution of the salts, that these maxima in the curves would probably be much more pronounced. Their results show that, at the higher temperatures, there is a marked decrease in dissociation. In their work they used a steel bomb lined with platinum, which would eliminate any error arising from the solubility of glass.

There is more evidence available for the existence of conductivity-temperature curves containing maxima and perhaps an upper conductivity zero, as was pointed out by Messrs. Bousfield and Lowry, in the case of non-aqueous solvents.

[1] Z. physik. Chem., **4**, 96 (1889).
[2] Wied. Ann., **43**, 212 (1891).
[3] Z. physik. Chem., **18**, 155 (1895).
[4] Ann. d. Phys., **5**, 276 (1901).
[5] Z. physik. Chem., **46**, 323 (1904). J. Am. Chem. Soc., **262**, 134 (1904).

Franklin and Kraus[1] found that, at high temperatures, the conductivity of solutions in liquid ammonia decreases with rise in temperature. Miss Maltby[2] has shown that, even at atmospheric temperatures, the conductivity of an ethereal solution of hydrochloric acid decreases as the temperature rises. Cattaneos[3] obtained negative temperature coefficients in solutions in ether, alcohol and glycerol. Hagenbach[4] obtained maxima in the conductivity-temperature curves at about 120°, in solutions of several salts in liquid sulphur dioxide. Walden and Centnerzwer[5] determined the conductivity of hydrochloric acid and a number of organic compounds, dissolved in sulphur dioxide. The results with hydrochloric acid are especially interesting, because it is known to be of itself a non-electrolyte, and to possess no power of undergoing dissociation, unless brought in contact with a dissociating medium. At the critical temperature of the solvent, the conductivity decreased to a zero value, which is, therefore, identical with the upper conductivity zero of the solution. Kraus[6] investigated solutions of various electrolytes dissolved in methyl and ethyl alcohols. He studied the conductivity up to, through and beyond the critical temperature of the solvents, and showed that the conductivity-temperature curve passes through a maximum with rise in temperature. The maximum in the case of solutions in methyl alcohol occurs at 150°, while in solutions of ethyl alcohol it is at 100°. In the case of solutions of potassium iodide, dissolved in methyl and ethyl alcohols, the conductivities did not reach a zero value at the critical temperature of the solvent. Although the resistance attained considerable magnitude, the solutions still remained conductors beyond the critical temperature. Since potassium iodide is an electrolyte *per se*, this is what we would expect, according to the idea advanced by Bousfield and Lowry. Although these interesting results point to the probable correctness of the Bousfield-Lowry hypothesis, concerning the effect of temperature on the con-

[1] Am. Chem. J., **24**, 83 (1900).
[2] Z. physik. Chem., **18**, 133 (1895).
[3] Rend. Lincei, [5], **2**, 1, 295 (1893); *Ibid.*, [5], **2**, 2, 112 (1893).
[4] Ann. d. Phys., [5], **2**, 276 (1901).
[5] Z. physik. Chem., **39**, 549 (1902).
[6] Phys. Rev., **18**, 40 (1904).

ductivity of acids and salts, nevertheless, we may fairly question whether there is enough experimental evidence to justify any general conclusion. However, there is, undoubtedly, sufficient evidence to support the idea that the effect of temperature on conductivity, over a wide range of temperature, can only be represented by inflected conductivity-temperature curves, which contain a maximum point.

The most important point in the paper of Bousfield and Lowry and one that has been generally overlooked, is the fact that the normal form of the conductivity-temperature curve, for a composite electrolyte, is an inflected curve which contains a maximum. A wide-spread impression exists, however, that an inflection in the conductivity-temperature curve indicates some abnormal change in the character of the solution. This impression has been strengthened, if indeed it has not been created, by the general adoption of a linear or parabolic formula to express the influence of temperature on conductivity. Kohlrausch makes no reference to the existence of inflected curves which contain a maximum point. Trotsch,[1] who observed inflections in the case of a number of sulphates and chlorides of copper and cobalt, regarded them as due to the decomposition of hydrates existing in the solution.

Purpose of this Investigation.

Having given a brief review of what has been done on the effect of temperature on dissociation, conductivity and the temperature coefficient of conductivity, we shall now take up the work, the results of which are recorded in this paper. It is well known that different types of compounds show different degrees of dissociation and, as we have seen, the exact effect of temperature on dissociation, over the ordinary range of temperature, say from 0°–35°, has not, as yet, been fully established for any considerable number of substances. This particular problem, including its connection with other important researches along this same line, together with various hypotheses which have been proposed in recent years, is the object of this investigation. The

[1] Ann. d. Phys. [3], 41, 259 (1890).

temperature coefficients of conductivity, expressed in percentage of conductivity units, have also been worked out according to the Kohlrausch formula, and the effect of temperature on these temperature coefficients has been studied. In addition to this, the temperature coefficients, expressed in conductivity units, or increments of conductivity with rise in temperature, have been calculated and the effect of temperature on these increments has been investigated.

EXPERIMENTAL PART.

Apparatus.

The Kohlrausch method of measuring conductivity was used throughout this investigation. The bridge-wire was of "manganin" and was calibrated by the method of Strouhal and Barus.[1]

The resistance coils were standardized and found to be accurate to within 0.04 per cent.

The conductivity cells were of the form used by Jones and Lindsay.[2] They differed from the ordinary Arrhenius cells in that they were provided with a ground-glass stopper to prevent evaporation. The electrodes were cut from thick sheet platinum, and into each circular plate a stout platinum wire, about an inch in length, was welded. Glass tubes were sealed on to the platinum wires and electrode plates by means of sealing-glass. The electrodes were then treated in the manner recommended by Whetham.[3] They were first coated with platinum black in the usual manner, and afterwards heated to a high temperature in the flame of a blast-lamp. Electrodes coated with platinum black have the property of absorbing a small amount of salt from the solution and of giving some of it up again when water, or a more dilute solution, is placed in the cell. The investigation of very dilute solutions is thus rendered less accurate. The heating process gives a gray surface, which does not absorb any appreciable quantity of salt. The oxidizing action of the platinum black is also avoided by this treatment.

[1] Wied. Ann., **10**, 326 (1880).
[2] Am. Chem. J., **28**, 329 (1902).
[3] Phil. Trans., **94**, [A], 321 (1900).

The tubes carrying the electrodes, thus treated, were forced through thin rubber tubing and inserted into the glass tubes in the cell cap. Hot sealing-wax was then carefully poured over the joint, on the outside of the cap. The cell constants were determined by means of solutions of potassium chloride having a concentration 0.02 N for cells designed for concentrated solutions; for cells intended for dilute solutions a 0.002 N solution of potassium chloride was employed. Each cell was adjusted for a particular range of dilution. The adjustment was made by raising or lowering the electrodes, having first heated the sealing-wax on the cap. When the cells were finally adjusted the constants were carefully redetermined.

The determination of the cell constants was carried out in a manner somewhat different from that ordinarily employed. When a cell containing a solution is placed in a thermostat, at 25°, and allowed to come to constant temperature, air-bubbles collect around the electrodes. It is difficult to dislodge the bubbles without changing the temperature of the solution somewhat. By moving the electrodes the bubbles can be dislodged, but some minutes must elapse in order to establish temperature equilibrium before readings can be made. In the meantime more bubbles may have collected. This difficulty was avoided by first placing the cells in a zero-bath and allowing them to remain there about a quarter of an hour. They were then removed to the thermostat-bath at 25° and allowed to remain nearly an hour. By this mode of procedure no bubbles, or at least only a very few, collected on the electrodes. After the readings were taken the cells were allowed to remain a quarter of an hour longer, and duplicate readings were made. The second readings were nearly always identical with the first, within the limit of error of reading. The following day the whole process was repeated. With careful manipulation, cells calibrated in this manner give very accurate results and the variation in the cell constants, produced by continual use, is very small. The constants were, however, redetermined every few weeks, since small particles of platinum are liable to be removed by abrasion.

Four thermostats were used in this work, for the various temperatures ranging from 0° to 35°. The zero-bath was of the type used by Jones and Lindsay,[1] though somewhat larger. It consisted of an outer and inner vessel. The inner vessel and the annular space between the two were filled with finely crushed ice. The outer portion of ice was moistened with a small quantity of distilled water, and to the ice in the inner vessel a larger amount of distilled water was added. The inner vessel contained a shelf for supporting the cells. Cells immersed in such a bath could be kept for any desired period at 0°.02 to 0°.05. The bath for the temperature next above zero was prepared in the following manner: A constant stream of hydrant water was passed through a large vessel, the water, being admitted at the bottom and allowed to flow out at the top, was kept thoroughly stirred by means of a small, hot-air engine. After running about an hour the temperature of the water remained almost constant. A small flame was now placed under the bath and by proper adjustment of this and of the rate of flow of the tap water, a constant temperature could be easily maintained. The 25° and 35° baths were obtained in the ordinary way and were stirred by hot-air engines. The Ostwald thermo-regulator was used and the temperature remained constant to 0°.005. The thermometers employed could be accurately read to 0°.02. The burettes and measuring flasks were carefully calibrated for 20°, according to the method of Morse and Blalock.[2]

Preparation of the Solutions.

In the preparation of the solutions, Kahlbaum's purest materials were invariably employed. These were, however, always tested for any possible impurities, which were removed. In some cases the standardization was effected by simply weighing the substance. When this was not possible the solutions were standardized by analysis. In making up a series of dilutions from the mother-solution of any substance, the temperature was, of course, kept under control and usually to within 0°.5 of the calibration temperature of the burettes and measuring flasks. The

[1] Am. Chem. J., **28**, 329 (1902).
[2] *Ibid.*, **16**, 479 (1894).

various concentrations were obtained by successive dilution, the mother-solution being the starting-point.

The water used in preparing the solutions was purified according to the method of Jones and Mackay.[1] Ordinary distilled water, after the addition of potassium bichromate and sulphuric acid, was redistilled. The distillate was distilled from acidified potassium bichromate and then, finally, from barium hydroxide. Water purified by this method gives a conductivity, at 25°, varying from 1.5 to 2.0×10^{-6}. The water correction, which must be applied to the values of the molecular conductivity at a given dilution (μ_v), usually does not attain an appreciable value until a dilution of about N/512 is reached.

Conductivity Measurements.

In making the conductivity measurements, from three to five different resistances were used for every solution. The values for the molecular conductivity (μ_v), given in the tables, are, therefore, the mean of several determinations.

Experimental Results.

In discussing the experimental results, the first substance considered is ammonium chloride. As the numerical results given in each table on ammonium chloride are of considerable interest in connection with certain theoretical ideas which have been advanced in recent years, the data given in each table will be discussed separately. After a full discussion of the results with ammonium chloride, the results with the other electrolytes will be taken up in order and the data discussed collectively, because the results with the other electrolytes are of the same general character as those with ammonium chloride, except in the case of acids.

Ammonium Chloride.

The pure salt was dried by heating in an air-bath, for several hours, at 120°, after which it was placed in a desicca-

[1] Am. Chem. J., **19**, 91 (1897).

tor until used. In making up the solutions, the exact amount of the salt necessary to make a 0.05 N solution was weighed out and introduced into a measuring flask.

Table I.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 14°.5.	μ_v 25°.	μ_v 35°.
2	62.76	89.86	109.2	129.9
8	66.17	96.11	118.6	142.8
16	68.02	99.26	123.2	148.2
32	70.2	102.4	127.6	153.7
128	73.08	107.6	133.4	161.4
512	74.39	109.8	136.8	165.4
1024	74.84	110.5	137.8	167.2

In Table I. are given the values of the molecular conductivities of the various solutions of ammonium chloride at the different temperatures; v is the volume of the solution which contains a gram-molecular weight of the electrolyte and μ is the molecular conductivity at the temperature in question. The molecular conductivity increases, of course, with rise in temperature and with increase in the dilution of the solution.

Table II.—Comparisons with the Work of Kohlrausch.

v.	Kohlrausch. μ_v 18°.	Calculated from our work. μ_v 18°.
2	94.8	96.3
8	...	103.6
10	103.5	...
16	...	107.2
20	107.8	...
32	...	110.8
33.3	110.1	...
100	114.2	...
128	...	116.2
500	118.0	...
512	...	118.8
1000	119.0	...
1024	...	119.6
1667	119.7	...

In Table II. is given a comparison of our results with those of Kohlrausch. The experimental results were obtained by Kohlrausch at 18°. Our work was not done at 18°. However, by applying our temperature coefficients, either in conductivity units or percentage, we can easily calculate our experimental results over to the temperature 18° and thus make comparisons with the experimental values of Kohlrausch. It is apparent, from the values given in the table, that there is a very close agreement between the two sets of results. In certain cases, where the dilutions are nearly the same, the figures are almost identical. Wherever such comparisons are made, the column headed "calculated" are from our own results.

Table III.—Temperature Coefficients in Conductivity Units.

v.	0°–14°.5.	14°.5–25°.	25°–35°.
2	1.87	1.84	2.07
8	2.06	2.14	2.42
16	2.15	2.28	2.50
32	2.22	2.40	2.61
128	2.38	2.46	2.80
512	2.44	2.57	2.86
1024	2.46	2.60	2.94

Table III. gives the values of the temperature coefficients of conductivity expressed in conductivity units. They are calculated from the formula

$$\frac{\mu_v t_2 - \mu_v t_1}{t_2 - t_1} = \text{coefficient.}$$

Where μ_v represents the molecular conductivity, t_2 is the higher temperature and t_1 the lower temperature. The figures given are really increments of conductivity with rise in temperature. *The increments increase with rise in temperature and increase in dilution. This is always the case with salts*, while with acids,

as we shall see, the increments increase with dilution, but decrease with rise in temperature. It is hardly necessary to point out the fact that these temperature coefficients are useful in calculating the conductivity of a solution of ammonium chloride at one temperature from the known conductivity at another temperature. By the aid of these temperature coefficients we can calculate conductivity values somewhat more readily than by the percentage temperature coefficients usually employed.

Table IV.—Temperature Coefficients in Per Cent.

v.	0°–14°.5.	14°.5–25°.	25°–35°.
2	2.98	2.05	1.90
8	3.11	2.23	2.02
16	3.16	2.30	2.02
32	3.16	2.34	2.04
128	3.26	2.29	2.10
512	3.29	2.34	2.09
1024	3.29	2.35	2.13

In this table the temperature coefficients of conductivity, expressed in percentage of conductivity units, are given. They are calculated according to the well-known Kohlrausch formula, expressed in the symbols used by Ostwald and others and multiplied by 100. The formula, as it was applied, is

$$\frac{\mu_v t_2 - \mu_v t_1}{t_2 - t_1} \cdot \frac{1}{\mu_v t_1} \times 100.$$

Where μ_v represents the molecular conductivity, t_2 is the higher and t_1 the lower temperature. The figures show that *the percentage temperature coefficients decrease with rise in tem-*

perature. The molecular conductivity increases with rise in temperature, as was shown by Table I., but the *percentage of increase decreases.* This fact is especially interesting when considered in connection with the next table.

Table V.—Percentage Dissociation.

v.	α 0°.	α 14°.5.	α 25°.	α 35°.
2	84.0	81.3	79.2	77.7
8	88.4	87.0	86.1	85.4
16	90.8	89.8	89.4	88.6
32	93.8	92.7	92.6	91.9
128	97.6	97.4	96.8	96.5
512	99.4	99.4	99.3	98.9
1024	100.0	100.0	100.0	100.0

Table V. gives the values of α, the percentage of dissociation, of ammonium chloride at the various temperatures for the different dilutions. α is calculated from the formula

$$\alpha = \frac{\mu_v}{\mu\infty} \times 100,$$

where μ_v represents the molecular conductivity and $\mu\infty$ the molecular conductivity at complete dissociation. In this case

$$\mu\infty = \mu_v \text{ at } 1024 \text{ liters.}$$

It is apparent from the table, that *the percentage of dissociation decreases with rise in temperature.* As the temperature increases from 0° to 35°, the values of α decrease, except in the most dilute solutions, where the salt is completely, or almost completely dissociated. Of course, here we should not expect to notice a large decrease, except over a wide range of temperature.

Ammonium Bromide.

The pure salt was heated in an air-bath, for several hours, at 120°, after which it was dried in a desiccator for some days. The mother-solution was prepared by direct weighing; the other solutions were made by diluting the original one. As is shown by the numerical values given in the tables, the same kind of results are obtained with ammonium bromide as with ammonium chloride. In Table VI. the molecular conductivities are seen to increase with rise in temperature. Table VII. shows that the temperature coefficients of conductivity, expressed in conductivity units, increase with temperature. In Table VIII. the percentage temperature coefficients of conductivity decrease with rise in temperature, and Table IX. shows a decrease in dissociation with rise in temperature.

No table is given for ammonium bromide, which shows how our values of the molecular conductivities, calculated by means of the temperature coefficients, compare with those obtained experimentally by other investigators. It was not considered necessary in each case to include these tables, as a few will suffice to show the general agreement.

Table VI.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 12°.5.	μ_v 25°.	μ_v 35°.
2	67.26	89.81	115.1	136.7
8	69.36	95.44	123.6	146.8
16	71.53	98.06	127.4	153.3
32	73.50	101.1	131.7	158.0
128	76.18	105.5	137.9	165.0
512	77.55	107.8	141.3	168.9
1024	77.06	107.5	140.9	169.5

Table VII.—Temperature Coefficients in Conductivity Units.

v.	0°–12°.5.	12°.5–25°.	25°–35°.
2	1.80	2.02	2.16
8	2.09	2.25	2.32
16	2.12	2.35	2.59
32	2.21	2.45	2.63
128	2.35	2.59	2.71
512	2.42	2.68	2.76
1024	2.43	2.67	2.86

Table VIII.—Temperature Coefficients in Per Cent.

v.	0°–12°.5.	12°.5–25°.	25°–35°.
2	2.68	2.25	1.88
8	3.01	2.36	1.88
16	2.96	2.40	2.03
32	3.01	2.42	2.00
128	3.08	2.46	1.98
512	3.12	2.49	1.95
1024	3.16	2.49	2.03

Table IX.—Percentage Dissociation.

v.	α 0°.	α 12°.5.	α 25°.	α 35°.
2	87.3	83.5	81.7	80.6
8	90.0	88.8	87.7	86.6
16	92.8	91.2	90.4	90.4
32	95.4	94.1	93.5	93.2
128	98.9	98.1	97.9	97.3
512	100.0	100.0	100.0	99.6
1024	100.0	100.0	100.0	100.0

Sodium Bromide.

The salt was dried by heating for several hours, at 120°, after which it was placed in a desiccator until used. The mother-solution was made up by direct weighing and the other solutions obtained by dilution. Conductivity measurements were made at only three different temperatures. However, results of the same character were obtained as with the preceding salts. Ostwald has measured the conductivities of a few dilutions of sodium bromide, at 25°. His results are included in Table X. A comparison of the two series of results shows a close agreement.

Table X.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 11°.8.	μ_v 25°.	Ostwald. μ_v 25°.
2	51.46	69.24	91.9	...
8	55.36	75.26	100.3	...
16	57.35	78.17	105.1	...
32	58.79	80.03	107.7	107.9
128	61.23	84.35	113.3	113.8
512	63.02	87.17	116.8	118.6
2048	64.48	89.34	121.1	119.9

Table XI.—Temperature Coefficients in Conductivity Units.

v.	0°–11°.8.	11°.8–25°.
2	1.50	1.72
8	1.69	1.90
16	1.76	2.04
32	1.80	2.10
128	1.96	2.19
512	2.04	2.24
2048	2.11	2.40

Table XII.—Temperature Coefficients in Per Cent.

v.	0°–11°.8.	11°.8–25°.
2	2.91	2.48
8	3.05	2.52
16	3.07	2.61
32	3.06	2.62
128	3.20	2.60
512	3.24	2.57
2048	3.27	2.69

Table XIII.—Percentage Dissociation.

v.	α 0°.	α 11°.8.	α 25°.
2	79.8	77.5	75.9
8	85.9	84.2	82.8
16	88.9	87.5	86.8
32	91.2	89.6	88.9
128	95.0	94.4	93.6
512	97.7	97.6	96.4
2048	100.0	100.0	100.0

Sodium Iodide.

The salt was dried by heating, for some hours, at 120° and then placed in a desiccator until used. The original solution was made up by direct weighing and the other solutions by diluting. As is shown by the numerical values given in the tables, the effect of temperature on conductivity and dissociation is the same as with the other salts.

Table XIV.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 16°.	μ_v 25°.	μ_v 35°.
2	51.90	77.22	92.73	111.6
8	55.26	83.52	100.4	121.6
16	57.03	86.36	104.2	125.8
32	58.62	89.02	107.4	130.6
128	60.97	93.20	112.5	136.8
512	61.81	94.91	114.7	139.3
1024	63.14	96.28	116.4	141.8
2048	64.51	98.4	119.1	144.5

Table XV.—Temperature Coefficients in Conductivity Units.

v.	0°–16°.	16°–25°.	25°–35°.
2	1.58	1.72	1.88
8	1.77	1.88	2.12
16	1.83	1.98	2.16
32	1.90	2.04	2.32
128	2.01	2.14	2.43
512	2.07	2.20	2.46
1024	2.07	2.24	2.54
2048	2.12	2.30	2.54

Table XVI.—Temperature Coefficients in Per Cent.

v.	0°–16°.	16°–25°.	25°–35°.
2	3.04	2.23	2.03
8	3.20	2.25	2.11
16	3.21	2.29	2.07
32	3.24	2.29	2.16
128	3.30	2.30	2.16
512	3.35	2.32	2.14
1024	3.28	2.33	2.18
2048	3.29	2.34	2.13

Table XVII.—Percentage Dissociation.

v.	α 0°.	α 16°.	α 25°.	α 35°.
2	80.5	78.5	77.9	77.2
8	85.7	84.9	84.3	84.2
16	88.4	87.8	87.5	87.1
32	90.9	90.5	90.2	90.4
128	94.5	94.7	94.5	94.7
512	95.8	96.5	96.3	96.4
1024	97.9	97.8	97.7	98.1
2048	100.0	100.0	100.0	100.0

Sodium Carbonate.

The salt was dried for some hours, at 120° and then kept in a desiccator until used. Conductivity measurements were made at only three temperatures. In Table XIX. is given a comparison of the results obtained by Kohlrausch at 18°, with the values of the molecular conductivities calculated by means of the temperature coefficients between 15°.3 and 25°. As is shown by the table, there is a close agreement between the two sets of results.

Table XVIII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 15°.3.	μ_v 25°.
2	50.99	78.94	100.4
8	70.7	109.1	137.8
16	79.75	123.8	155.4
32	87.28	134.7	170.8
128	99.16	155.4	197.9
512	105.8	166.9	209.6
1024	110.8	173.9	218.1

Table XIX.—Comparison with the Work of Kohlrausch.

	Kohlrausch.	Calculated.
v.	μ_v 18°.	μ_v 18°.
2	85.4	84.91
4	102.0	. .
8	. .	117.09
16	. .	132.6
20	136.4	. .
32	. .	144.7
40	150.2	. .
128	. .	167.2
200	179.8	. .

Table XX.—Temperature Coefficients in Conductivity Units.

v.	0°–15°.3.	15°.3–25°.
2	1.83	2.21
8	2.51	2.96
16	2.88	3.26
32	3.10	3.72
128	3.67	4.38
512	3.99	4.40
1024	4.12	4.56

Table XXI.—Temperature Coefficients in Per Cent.

v.	0°–15°.3.	15°.3–25°.
2	3.59	2.80
8	3.55	2.71
16	3.61	2.64
32	3.55	2.77
128	3.70	2.82
512	3.77	2.64
1024	3.72	2.62

Table XXII.—Percentage Dissociation.

v.	α 0°.	α 15°.3.	α 25°.
2	46.0	45.4	46.0
8	63.8	62.7	63.2
16	72.0	71.2	71.3
32	78.8	77.5	78.3
128	89.5	89.4	90.7
512	95.5	95.9	96.1
1024	100.0	100.0	100.0

Sodium Acetate.

The sodium acetate used was a specimen of the fused salt, obtained from Kahlbaum. After purification it was dried in an air-bath, for several days, at 120°. This treatment was necessary to bring it to constant weight. The original solution was made up by weight. Results of the same general character were obtained with sodium acetate as with the other salts.

The temperature coefficients, in conductivity units, are small, as might be expected from the comparatively small conductivity of the salt.

Table XXIII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 13°.6.	μ_v 25°.	μ_v 35°.
2	28.39	41.93	54.86	67.06
8	34.30	50.73	66.25	81.09
16	36.37	53.86	70.17	86.01
32	38.11	56.59	73.81	90.55
128	40.41	60.22	78.32	96.43
512	41.21	61.63	80.14	99.34
1024	40.65	61.15	79.12	98.6
2048	41.28	61.97	80.14	99.4

Table XXIV.—Temperature Coefficients in Conductivity Units.

v.	0°–13°.6.	13°.6–25°.	25°–35°.
2	0.996	1.13	1.22
8	1.21	1.36	1.48
16	1.29	1.43	1.58
32	1.36	1.51	1.67
128	1.46	1.59	1.81
512	1.50	1.62	1.92
1024	1.51	1.58	1.95
2048	1.52	1.59	1.93

Table XXV.—Temperature Coefficients in Per Cent.

v.	0°–13°.6.	13°.6–25°.	25°–35°.
2	3.51	2.69	2.22
8	3.53	2.68	2.23
16	3.52	2.66	2.25
32	3.57	2.67	2.26
128	3.61	2.64	2.31
512	3.67	2.63	2.38
1024	3.71	2.58	2.46
2048	3.68	2.57	2.41

Table XXVI.—Percentage Dissociation.

v.	α 0°.	α 13°.6.	α 25°.	α 35°.
2	68.9	67.9	68.5	67.5
8	83.2	82.3	82.7	81.6
16	88.3	87.4	87.6	86.6
32	92.2	91.8	92.1	91.2
128	98.1	97.7	97.7	97.1
512	100.0	100.0	100.0	100.0

Potassium Chloride.

The salt was recrystallized 5 times. It was then dried for several days, in an air-bath, at 150° and afterwards preserved in a desiccator until used. Conductivity measurements were made at 5 different temperatures. In Table XXVIII., the calculated values of the molecular conductivities, at 18°, show a very close agreement with those obtained experimentally by Kohlrausch at the same temperature.

Table XXVII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 4°.3.	μ_v 15°.5.	μ_v 25°.	μ_v 35°.
2	62.96	70.09	91.09	109.5	130.8
8	66.47	74.48	98.24	118.6	142.5
16	68.4	76.95	101.5	122.9	147.7
32	70.27	78.95	104.9	126.8	152.5
128	73.0	82.25	109.4	132.4	159.9
512	74.24	83.59	111.9	135.5	163.0
1024	75.14	84.59	112.9	137.0	165.4

Table XXVIII.—Comparison with the Work of Kohlrausch.

	Kohlrausch.	Calculated.
v.	μ_v 18°.	μ_v 18°.
2	95.8	95.9
8	...	103.6
10	104.7	...
16	...	107.0
20	108.3	...
32	...	110.7
33.3	110.7	...
100	114.7	...
128	...	115.5
500	118.5	...
512	...	118.1
1000	119.3	...
1024	...	119.3
1667	119.9	...

Table XXIX.—Temperature Coefficients in Conductivity Units.

v.	0°–4°.3.	4°.3–15°.5.	15°.5–25°.	25°–35°.
2	1.66	1.88	1.94	2.13
8	1.86	2.12	2.14	2.39
16	1.99	2.19	2.25	2.48
32	2.02	2.32	2.31	2.57
128	2.15	2.42	2.42	2.75
512	2.17	2.53	2.48	2.75
1024	2.20	2.53	2.54	2.84

Table XXX.—Temperature Coefficients in Per Cent.

v.	0°–4°.3.	4°.3–15°.5.	15°.5–25°.	25°–35°.
2	2.63	2.68	2.13	1.94
8	2.78	2.80	2.18	2.01
16	2.91	2.85	2.22	2.02
32	2.87	2.94	2.20	2.03
128	2.94	2.94	2.21	2.08
512	2.92	3.03	2.22	2.03
1024	2.93	2.99	2.25	2.07

Table XXXI.—Percentage Dissociation.

v.	α 0°.	α 4°.3.	α 15°.5.	α 25°.	α 35°.
2	83.8	82.9	80.7	79.9	79.0
8	88.5	88.0	87.0	86.6	86.2
16	91.0	91.0	89.9	89.7	89.3
32	93.5	93.3	92.0	92.6	92.2
128	97.2	97.2	96.9	96.6	96.7
512	98.8	98.8	99.1	98.9	98.5
1024	100.0	100.0	100.0	100.0	100.0

Potassium Bromide.

The sample of potassium bromide, which was used, was prepared in the same manner as the preceding salts. It was dried for some hours, in an air-bath, at 110° and then placed in a desiccator until used. In Table XXXIII. is given a comparison of our calculated results with those obtained experimentally by Krannhals, at 18°. The two series of values agree very closely. The same general rule holds for dissociation and temperature coefficients, as has been observed with the preceding compounds.

Table XXXII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 14°.5.	μ_v 25°.	μ_v 35°.
2	65.82	93.21	114.4	136.2
8	68.01	98.45	121.3	145.6
16	70.1	101.7	125.2	150.5
32	71.84	104.6	128.8	154.6
128	74.79	109.0	134.5	162.0
512	75.73	111.3	137.6	165.5
1024	79.23	115.6	143.5	172.6

Table XXXIII.—Comparison with the Work of Krannhals.

	Krannhals.	Calculated.
v.	μ_v 18°.	μ_v 18°.
2	98.2	100.3
8	105.7	106.1
16	110.0	109.5
32	113.0	112.7
128	117.0	117.5
256	118.8	...
512	...	120.1
1000	121.0	...
1024	...	124.9

Table XXXIV.—Temperature Coefficients in Conductivity Units.

v.	0°–14°.5.	14°.5–25°.	25°–35°.
2	1.89	2.02	2.18
8	2.10	2.18	2.43
16	2.18	2.24	2.53
32	2.26	2.30	2.58
128	2.35	2.43	2.75
512	2.45	2.50	2.79
1024	2.51	2.66	2.91

Table XXXV.—Temperature Coefficients in Per Cent.

v.	0°–14°.5.	14°.5–25°.	25°–35°.
2	2.87	2.17	1.90
8	3.09	2.21	2.00
16	3.07	2.20	2.02
32	3.15	2.20	2.00
128	3.14	2.23	2.04
512	3.24	2.25	2.03
1024	3.17	2.30	2.03

Table XXXVI.—Percentage Dissociation.

v.	α 0°.	α 14.5°.	α 25°.	α 35°.
2	83.1	80.6	79.7	78.9
8	85.8	85.2	84.5	84.4
16	88.5	88.0	87.2	87.2
32	90.8	90.5	89.8	89.6
128	94.4	94.3	93.7	93.9
512	95.6	96.3	95.9	95.9
1024	100.0	100.0	100.0	100.0

Potassium Iodide.

The potassium iodide was dried for several hours, at 110°. The original solution was made up by direct weighing. In Table XXXVIII. the comparisons of our figures for the molecular conductivities with the work of others, show close agreement. In some cases where the dilutions are the same, or very nearly the same, the numerical values are almost identical.

Table XXXVII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 10°.1.	μ_v 25°.	μ_v 35°.
2	65.78	83.88	112.8	133.7
8	68.45	88.18	120.7	144.5
16	70.17	90.51	124.5	148.4
32	71.90	93.32	128.0	153.0
128	74.41	96.67	133.7	160.2
512	76.35	98.91	137.3	165.9
1024	77.77	101.9	141.8	170.9
2048	79.2	104.9	147.2	177.2

Table XXXVIII.—Comparison with the Work of Others.

Ostwald.			Kohlrausch.	Calculated.
v.	μ_v 25°.	v.	μ_v 18°.	μ_v 18°.
	...	2	99.7	99.2
	...	8	...	105.4
	...	10	106.9	...
32	128.5	16	...	108.5
128	135.4	20	110.2	...
512	139.6	32	...	111.7
1024	140.7	33.3	112.3	...
	...	128	...	116.3
	...	166.7	117.6	...
	...	500	119.7	...
	...	512	...	119.2
	...	1000	120.3	...
	...	1024	...	123.0

Table XXXIX.—Temperature Coefficients in Conductivity Units.

v.	0°–10°.1.	10°.1–25°.	25°–35°.
2	1.79	1.94	2.09
8	1.95	2.18	2.38
16	2.01	2.28	2.39
32	2.12	2.33	2.50
128	2.20	2.48	2.65
512	2.23	2.58	2.86
1024	2.39	2.68	2.91
2048	2.54	2.84	3.00

Table XL.—Temperature Coefficients in Per Cent.

v.	0°–10°.1.	10°.1–25°.	25°–35°.
2	2.72	2.31	1.85
8	2.84	2.47	1.97
16	2.86	2.52	1.92
32	2.95	2.50	1.95
128	2.96	2.57	1.98
512	2.92	2.61	2.08
1024	3.07	2.63	2.05
2048	3.21	2.71	2.04

Table XLI.—Percentage Dissociation.

v.	α 0°.	α 10°.1.	α 25°.	α 35°.
2	83.1	80.0	76.6	75.5
8	86.4	84.1	82.0	81.5
16	88.6	86.3	84.6	83.7
32	90.8	89.0	87.0	86.3
128	94.0	92.1	90.8	90.4
512	96.4	94.3	93.3	93.6
1024	98.2	97.1	96.3	96.4
2048	100.0	100.0	100.0	100.0

Potassium Nitrate.

The specimen of potassium nitrate used was dried for 2 days, at 110° and then placed in a desiccator until used. The mother-solution was standardized by direct weighing. The comparisons of the molecular conductivities given in Table XLIII. show that our calculated values are practically the mean of those obtained experimentally by Kohlrausch and Krannhals, except in the very dilute solutions, where our values agree closely with those obtained by Kohlrausch.

Table XLII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 10°.	μ_v 25°.	μ_v 35°.
2	54.02	69.67	95.21	113.8
8	61.94	80.22	111.0	132.4
16	65.33	84.31	116.3	139.0
32	67.92	87.78	121.3	145.0
128	72.05	93.57	129.5	154.1
512	76.34	98.71	137.0	163.9
1024	76.31	99.8	139.6	166.7

Table XLIII.—Comparison with the Work of Others.

	Kohlrausch.	Calculated.	Krannhals.
v.	μ_v 18°.	μ_v 18°.	μ_v 18°.
2	83.9	83.3	83.1
8	...	96.6	95.6
10	103.7	...	...
16	...	101.4	100.3
20	106.7	...	...
32	...	105.7	104.3
100	114.0	...	...
128	...	112.7	109.3
500	118.0	...	...
512	...	119.2	...
1000	119.0	...	114.0
1024	...	121.1	...

Table XLIV.—Temperature Coefficients in Conductivity Units.

v.	0°–10°.	10°–25°.	25°–35°.
2	1.56	1.70	1.86
8	1.83	2.05	2.14
16	1.90	2.13	2.27
32	1.99	2.23	2.37
128	2.15	2.40	2.46
512	2.24	2.55	2.69
1024	2.35	2.65	2.71

Table XLV.—Temperature Coefficients in Per Cent.

v.	0°–10°.	10°–25°.	25°–35°.
2	2.89	2.44	1.95
8	2.95	2.56	1.93
16	2.91	2.53	1.91
32	2.93	2.54	1.95
128	2.98	2.56	1.82
512	2.93	2.58	1.96
1024	3.08	2.65	1.94

Table XLVI.—Percentage Dissociation.

v.	α 0°.	α 10°.	α 25°.	α 35°.
2	70.8	69.8	68.2	68.3
8	81.2	80.4	79.5	79.4
16	85.6	84.5	83.3	83.4
32	89.0	88.0	86.9	87.0
128	94.4	93.8	92.8	92.4
512	100.0	98.9	98.1	98.3
1024	100.0	100.0	100.0	100.0

Potassium Sulphate.

The specimen of salt used was dried for some hours, at 120° and then kept in a desiccator until used. The comparison of the molecular conductivities given in Table XLVIII. are not quite as close as in the case of certain other salts.

The temperature coefficients in conductivity units are large and the conductivity of the salt itself is comparatively large.

Table XLVII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 9°.5.	μ_v 25°.	μ_v 35°.
2	87.19	110.1	152.6	180.7
8	101.9	130.5	183.6	219.8
16	109.9	140.9	199.2	238.4
32	117.9	151.5	214.4	256.9
128	131.9	170.3	242.1	291.0
512	142.7	184.0	263.5	318.4
1024	145.0	187.0	268.0	325.0

Table XLVIII.—Comparison with the Work of Kohlrausch.

	Kohlrausch.	Calculated.
v.	μ_v 18°.	μ_v 18°.
2	134.4	133.4
4	147.2	...
8	...	159.6
16	...	172.9
20	179.4	...
32	...	186.0
40	191.8	...
128	...	209.7
200	219.6	...
512	...	227.6
1000	236.2	...
1024	...	231.4
2000	241.4	...

Table XLIX.—Temperature Coefficients in Conductivity Units.

v.	0°–9°.5.	9°.5–25°.	25°–35°.
2	2.41	2.74	2.81
8	3.01	3.43	3.62
16	3.26	3.76	3.92
32	3.54	4.06	4.25
128	4.04	4.63	4.89
512	4.35	5.13	5.49
1024	4.42	5.23	5.70

Table L.—Temperature Coefficients in Per Cent.

v.	0°–9°.5.	9°.5–25°.	25°–35°.
2	2.76	2.49	1.84
8	2.95	2.63	1.91
16	2.97	2.67	1.97
32	3.00	2.61	1.98
128	3.06	2.72	2.03
512	3.05	2.79	2.08
1024	3.05	2.79	2.13

Table LI.—Percentage Dissociation.

v.	α 0°.	α 9°.5.	α 25°.	α 35°.
2	60.1	58.9	56.9	55.6
8	70.3	69.8	68.5	67.6
16	75.8	75.4	74.3	73.4
32	81.3	81.0	80.0	79.1
128	91.0	91.0	90.3	89.5
512	98.4	98.4	98.3	98.0
1024	100.0	100.0	100.0	100.0

Potassium Bisulphate.

The sample of salt was dried for several hours, at 110° and preserved in a desiccator until used. The original solution was made up by direct weighing. Here, again, we find the same phenomena that have appeared in the preceding cases; the percentage temperature coefficients of conductivity and the percentage dissociation decrease with rise in temperature.

The temperature coefficients in conductivity units are very large and the conductivity of the salt itself is very large, because it is an acid salt and splits off the swift hydrogen ion.

Table LII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 12°.5.	μ_v 25°.	μ_v 35°.
2	153.8	184.0	207.6	220.6
8	182.1	222.9	254.2	274.1
16	201.2	248.8	286.6	310.0
32	223.6	280.7	323.7	353.1
128	263.1	336.9	401.0	446.4
512	291.8	383.9	467.1	531.0
2048	290.9	385.8	478.2	556.6
8192	291.2	401.0	496.0	569.0

Table LIII.—Temperature Coefficients in Conductivity Units.

v.	0°–12°.5.	12°.5–25°.	25°–35°.
2	2.42	1.89	1.30
8	3.82	2.50	1.99
16	3.81	3.02	2.34
32	4.57	3.44	2.94
128	5.90	5.13	4.54
512	7.37	6.66	6.39
2048	7.59	7.39	7.84
8192	8.78	7.60	7.30

Table LIV.—Temperature Coefficients in Per Cent.

v.	0°–12°.5.	12°.5–25°.	25°–35°.
2	1.57	1.03	0.63
8	2.10	1.12	0.78
16	1.89	1.21	0.82
32	2.04	1.23	0.91
128	2.24	1.52	1.13
512	3.21	1.73	1.37
2048	2.61	1.92	1.64
8192	3.01	1.89	1.47

Table LV.—Percentage Dissociation.

v.	α 0°.	α 12°.5.	α 25°.	α 35°.
2	52.8	45.9	41.9	38.8
8	62.5	55.6	51.3	48.2
16	69.1	62.0	57.8	54.5
32	76.8	70.0	65.3	62.1
128	90.3	84.0	80.8	78.5
512	100.0	95.7	94.2	93.3
2048	100.0	96.2	96.4	97.6
8192	100.0	100.0	100.0	100.0

Potassium Carbonate.

The salt was dried, for some hours, at 110°. The solutions were made up by direct weighing and dilution. The comparisons given in Table LVII. are not quite so concordant as in preceding cases. The conductivity measurements were made at only 3 temperatures.

Table LVI.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 17°.8.	μ_v 25°.
2	84.34	129.2	150.1
8	98.74	154.1	180.9
16	105.3	166.5	195.3
32	112.9	179.6	210.5
128	122.3	197.6	233.6
512	131.2	211.1	250.1

Table LVII.—Comparison with the Work of Kohlrausch.

	Kohlrausch.	Calculated.
v.	μ_v 18°.	μ_v 18°.
2	132.0	129.8
4	145.6	...
8	...	154.8
16	...	167.3
20	175.8	...
32	...	180.5
40	188.4	...
512	...	212.2
1000	239.8	...

Table LVIII.—Temperature Coefficients in Conductivity Units.

v.	0°–17°.8.	17°.8–25°.
2	2.52	2.90
8	3.11	3.72
16	3.44	4.00
32	3.75	4.29
128	4.23	5.00
512	4.49	5.42

Table LIX.—Temperature Coefficients in Per Cent.

v.	0°–17°.8.	17°.8–25°.
2	2.99	2.24
8	3.15	2.41
16	3.26	2.40
32	3.32	2.39
128	3.46	2.53
512	3.42	2.57

Table LX.—Percentage Dissociation.

v.	α 0°.	α 17°.8.	α 25°.
2	64.3	61.2	60.0
8	75.3	73.0	72.3
16	80.3	78.9	78.1
32	86.0	85.1	84.2
128	93.2	93.6	93.4
512	100.0	100.0	100.0

Potassium Ferrocyanide.

The sample of potassium ferrocyanide used was purified by repeated crystallization. The mother-solution was made up by direct weighing and the others obtained by dilution. In this case the effect of temperature on dissociation is very slight. The dissociation at 35° is 2 per cent less than at 0°, in a 0.25 N solution, showing a small, but distinct temperature effect in the more concentrated solutions. As we have seen, the decrease in dissociation with rise in temperature becomes greater as the concentration of the solution is increased. This salt is, therefore, no exception to the rule.

The temperature coefficients in conductivity units are the largest thus far met with, and the conductivity of the salt is very great, on account of the large number of ions into which it dissociates. The values of μ_v that are taken as $\mu\infty$ are probably somewhat too small, but they are the best that can be obtained in the circumstances.[1]

[1] Jones and Bassett: Am. Chem. J., 34, 313 (1905).

Table LXI.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 13°.1.	μ_v 25°.	μ_v 35°.
4	162.1	224.1	287.1	341.8
8	168.8	236.8	305.1	364.5
16	179.9	255.0	327.1	394.1
32	195.6	277.0	357.8	430.7
128	236.1	335.5	432.8	523.8
512	280.7	399.4	516.6	627.0
1024	295.1	421.4	546.5	660.0
2048	315.0	449.0	578.0	703.0
8192	328.0	467.0	599.0	724.0

Table LXII.—Temperature Coefficients in Conductivity Units.

v.	0°–13°.1.	13°.1–25°.	25°–35°.
4	4.73	5.29	5.47
8	5.19	5.74	5.94
16	5.73	6.06	6.70
32	6.21	6.79	7.29
128	7.59	8.18	9.10
512	9.06	9.85	11.04
1024	9.64	10.51	11.35
2048	10.23	10.84	12.50
8192	10.61	11.09	12.50

Table LXIII.—Temperature Coefficients in Per Cent.

v.	0°–13°.1.	13°.1–25°.	25°–35°.
4	2.91	2.36	1.91
8	3.08	2.42	1.62
16	3.19	2.38	2.05
32	3.17	2.45	2.04
128	3.21	2.44	2.10
512	3.22	2.47	2.14
1024	3.27	2.49	2.08
2048	3.24	2.41	2.16
8192	3.23	2.37	2.09

Table LXIV.—Percentage Dissociation.

v.	α 0°.	α 13°.1.	α 25°.	α 35°.
4	49.4	48.0	47.9	47.2
8	51.5	50.7	50.9	50.3
16	54.8	54.6	54.6	54.4
32	59.6	59.3	59.7	59.5
128	72.0	71.8	72.3	72.3
512	85.6	85.5	86.2	86.6
1024	90.0	90.2	91.2	91.2
2048	96.0	96.1	96.4	97.1
8192	100.0	100.0	100.0	100.0

Calcium Chloride.

The salt was dissolved in water and the strength of the solution determined by analysis, the calcium being weighed as calcium sulphate.

The temperature coefficients, in conductivity units, are large, as is the conductivity of the salt itself. The salt may show slight hydrolysis, which would affect the value of $\mu\infty$.

Table LXV.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 11°.5.	μ_v 25°.	μ_v 35°.
2	89.32	119.7	159.2	190.3
8	105.5	147.8	193.4	233.8
16	112.3	157.5	207.4	250.1
32	118.5	163.4	219.9	266.0
128	129.9	179.8	243.6	295.0
512	138.2	192.1	260.8	316.4
1024	137.8	191.8	261.2	317.3

Table LXVI.—Temperature Coefficients in Conductivity Units.

v.	0°–11°.5.	11°.5–25°.	25°–35°.
2	2.64	2.93	3.11
8	3.68	3.38	4.04
16	3.93	3.70	4.27
32	3.90	4.18	4.61
128	4.34	4.73	5.14
512	4.69	5.09	5.56
1024	4.70	5.14	5.61

Table LXVII.—Temperature Coefficients in Per Cent.

v.	0°–11°.5.	11°.5–25°.	25°–35°.
2	2.96	2.45	1.95
8	3.49	2.29	2.09
16	3.50	2.33	2.06
32	3.29	2.56	2.10
128	3.34	2.63	2.11
512	3.39	2.65	2.13
1024	3.41	2.68	2.15

Table LXVIII.—Percentage Dissociation.

v.	α 0°.	α 11°.5.	α 25°.	α 35°.
2	64.8	62.4	60.9	60.0
8	76.6	77.1	74.0	73.7
16	81.5	82.1	79.4	78.8
32	85.9	85.1	84.2	83.8
128	94.3	93.7	93.3	93.0
512	100.0	100.0	99.8	99.7
1024	100.0	100.0	100.0	100.0

Calcium Bromide.

The mother-solution of calcium bromide was standardized by analysis. The calcium was determined as the sulphate. We have, in this case, the same general temperature effect as that already noted for other substances. The percentage temperature coefficients of conductivity and the percentage dissociation decrease with rise in temperature.

The same remarks apply to the temperature coefficients in conductivity units and to the conductivity itself, as in the case of calcium chloride.

Table LXIX.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 14°.4.	μ_v 25°.	μ_v 35°.
2	85.95	122.7	151.0	181.1
8	97.74	144.0	177.5	214.8
16	103.0	150.5	188.4	227.6
32	108.2	158.4	199.0	240.5
128	117.3	173.3	217.9	265.0
512	122.9	182.0	229.7	278.5
1024	126.3	186.9	236.5	286.5
2048	126.8	188.2	239.5	291.5

Table LXX.—Temperature Coefficients in Conductivity Units.

v.	0°–14°.4.	14°.4–25°.	25°–35°.
2	2.55	2.67	3.01
8	3.21	3.16	3.73
16	3.30	3.58	3.92
32	3.49	3.83	4.15
128	3.89	4.21	4.71
512	4.10	4.50	4.88
1024	4.21	4.68	5.00
2048	4.26	4.84	5.20

Table LXXI.—Temperature Coefficients in Per Cent.

v.	0°–14°.4.	14°.4–25°.	25°–35°.
2	2.97	2.18	1.99
8	3.28	2.19	2.10
16	3.20	2.37	2.08
32	3.23	2.42	2.09
128	3.32	2.43	2.16
512	3.34	2.47	2.13
1024	3.33	2.50	2.11
2048	3.36	2.57	2.17

Table LXXII.—Percentage Dissociation.

v.	α 0°.	α 14°.4.	α 25°.	α 35°.
2	67.7	65.2	63.1	62.1
8	77.1	76.5	74.1	73.7
16	81.2	80.0	78.7	78.1
32	85.3	84.2	83.1	82.5
128	92.5	92.1	91.0	90.9
512	96.9	96.7	95.9	95.5
1024	99.6	99.3	98.7	98.3
2048	100.0	100.0	100.0	100.0

Strontium Bromide.

The strength of the original solution was determined by analysis, the strontium being weighed as the sulphate.

Table LXXIII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 13°.5.	μ_v 25°.	μ_v 35°.
2	88.03	122.1	153.8	183.1
8	100.0	141.8	180.6	217.2
16	103.7	148.1	190.0	228.1
32	110.0	157.2	202.2	243.9
128	117.8	170.6	219.1	267.1
512	128.8	185.4	239.1	289.9
1024	129.1	186.6	239.6	292.3

Table LXXIV.—Temperature Coefficients in Conductivity Units.

v.	0°–13°.5.	13°.5–25°.	25°–35°.
2	2.52	2.76	2.93
8	3.10	3.37	3.66
16	3.29	3.64	3.81
32	3.50	3.91	4.17
128	3.91	4.22	4.80
512	4.19	4.67	5.08
1024	4.26	4.61	5.27

Table LXXV.—Temperature Coefficients in Per Cent.

v.	0°–13°.5.	13°.5–25°.	25°–35°.
2	2.86	2.26	1.91
8	3.10	2.38	2.03
16	3.17	2.46	2.01
32	3.18	2.49	2.06
128	3.32	2.17	2.19
512	3.25	2.52	2.13
1024	3.30	2.47	2.20

Table LXXVI.—Percentage Dissociation.

v.	α 0°.	α 13°.5.	α 25°.	α 35°.
2	68.2	65.4	64.2	62.6
8	77.5	76.0	75.4	74.3
16	80.3	79.4	79.3	78.0
32	85.2	84.2	84.4	83.4
128	91.2	91.4	91.4	91.4
512	99.8	99.4	99.8	99.2
1024	100.0	100.0	100.0	100.0

Barium Chloride.

The sample of barium chloride was dried in an air-bath, for some hours, at 110°. The mother-solution was made up by direct weighing and the lesser concentrations obtained by dilution. The conductivity measurements were made at 5 different temperatures. In Table LXXIV., the calculated values of the molecular conductivities, at 18°, show a close agreement with those obtained, experimentally, by Kohlrausch and Krannhals, at the same temperature. In the case of dilute solutions, however, our values are somewhat lower.

Table LXXVII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 4°.6.	μ_v 16°.5.	μ_v 25°.	μ_v 35°.
2	86.62	96.61	128.2	150.0	178.6
8	99.06	112.3	151.1	179.0	215.3
16	105.2	119.5	161.2	191.6	230.4
64	116.2	132.4	180.2	215.2	260.3
256	125.1	142.7	194.7	232.9	282.6
512	126.5	144.3	197.2	235.5	286.2
1024	130.9	149.3	203.8	243.4	296.4
2048	132.7	151.2	206.3	247.1	300.5

Table LXXVIII.—Comparison with Work of Others.

	Kohlrausch.	Krannhals.	Calculated.
v.	μ_v 18°.	μ_v 18°.	μ_v 18°.
2	131.6	131.0	132.0
8	...	154.0	156.0
16	...	163.0	166.6
20	172.2	....	...
32	...	170.0	...
40	180.8	...	...
64	...	...	186.4
66.7	187.8	...	...
128	...	192.0	...
200	201.2	...	...
256	...	...	201.4
333	206.2	...	...
512	...	212.0	204.0
1000	214.8	...	...
1024	...	...	211.0
2000	218.4	224.0	...
2048	...	...	213.5

Table LXXIX.—Temperature Coefficients in Conductivity Units.

v.	0°–4°.6.	4°.6–16°.5.	16°.5–25°.	25°–35°.
2	2.17	2.66	2.56	2.86
8	2.88	3.26	3.28	3.63
16	3.11	3.50	3.58	3.88
64	3.52	4.02	4.12	4.51
256	3.83	4.36	4.49	4.97
512	3.87	4.45	4.51	5.07
1024	4.00	4.57	4.66	5.30
2048	4.02	4.63	4.80	5.34

Table LXXX.—Temperature Coefficients in Per Cent.

v.	0°–4°.6.	4°.6–16°.5.	16°.5–25°.	25°–35°.
2	2.51	2.75	2.00	1.91
8	2.91	2.90	2.17	2.02
16	2.96	2.93	2.22	2.03
64	3.03	3.04	2.29	2.10
256	3.06	3.06	2.30	2.13
512	3.06	3.08	2.29	2.19
1024	3.05	3.06	2.28	2.18
2048	3.03	3.06	2.33	2.16

Table LXXXI.—Percentage Dissociation.

v.	α 0°.	α 4°.6.	α 16°.5.	α 25°.	α 35°.
2	65.3	63.9	62.1	60.7	59.4
8	74.6	74.3	73.2	72.4	71.6
16	79.3	79.0	78.1	77.5	76.6
64	87.6	87.6	87.3	87.1	86.6
256	94.3	94.4	94.4	94.3	94.0
512	95.3	95.4	95.6	95.3	95.2
1024	98.6	98.7	98.8	98.5	98.6
2048	100.0	100.0	100.0	100.0	100.0

Magnesium Chloride.

The original solution was standardized gravimetrically, by determining the chlorine as silver chloride. As is shown by the tables, the effect of temperature on dissociation and on the temperature coefficient of conductivity, expressed in percentage of conductivity units, is of the same general nature as in the case of the other substances we have considered. In Tables LXXXII. and LXXXIII. the same temperature effect is likewise noticed.

Table LXXXII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 14°.9.	μ_v 25°.	μ_v 35°.
2	67.59	99.09	122.8	148.3
8	81.35	120.8	150.3	182.5
16	86.87	129.6	161.2	195.2
32	92.26	137.4	171.7	208.4
128	100.3	151.6	189.2	231.4
512	105.3	159.8	200.6	245.8
1024	106.9	162.5	203.2	249.1

Table LXXXIII.—Temperature Coefficients in Conductivity Units.

v.	0°-14°.9.	14°.9-25°.	25°-35°.
2	2.11	2.35	2.55
8	2.65	2.92	3.22
16	2.87	3.13	3.40
32	3.03	3.40	3.67
128	3.44	3.72	4.22
512	3.66	4.03	4.52
1024	3.73	4.03	4.59

Table LXXXIV.—Temperature Coefficients in Per Cent.

v.	0°-14°.9.	14°.9-25°.	25°-35°.
2	3.12	2.37	2.08
8	3.26	2.42	2.14
16	3.30	2.42	2.11
32	3.28	2.47	2.13
128	3.43	2.45	2.22
512	3.48	2.59	2.25
1024	3.49	2.48	2.26

Table LXXXV.—Percentage Dissociation.

v.	α 0°.	α 14°.9.	α 25°.	α 35°.
2	63.2	61.0	60.4	59.5
8	76.1	74.3	74.0	73.3
16	81.3	79.8	79.3	78.4
32	86.3	84.6	84.5	83.7
128	93.8	93.3	93.1	92.9
512	98.5	98.3	98.7	98.7
1024	100.0	100.0	100.0	100.0

Zinc Sulphate.

The specimen of salt used was dried for several days, in an air-bath, at 110°. This was found necessary to bring it to constant weight. It was preserved in a desiccator until required. In Table LXXXVII. the comparison of our values of the molecular conductivities, with the results obtained experimentally by Kohlrausch, at 18°, shows a very close agreement. Conductivity measurements, in the case of this salt, were made at only 3 temperatures.

Table LXXXVI.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 15°.	μ_v 25°.
2	30.57	45.56	56.62
8	43.20	64.74	80.01
16	50.99	75.20	93.6
32	59.37	86.96	108.8
128	76.61	115.8	144.8
512	97.0	147.3	185.1
1024	104.7	156.9	197.8
2048	113.3	170.4	213.0
8192	117.0	176.0	218.0

Table LXXXVII.—Comparison with the Work of Kohlrausch.

	Kohlrausch.	Calculated.
v.	μ_v 18°.	μ_v 18°.
2	49.8	48.89
4	60.4	. .
8	. .	69.33
16	. .	80.72
20	86.2	. .
1000	172.2	. .
1024	. .	169.14
2000	183.8	. .
2048	. .	183.3

Table LXXXVIII.—Temperature Coefficients in Conductivity Units.

v.	0°.15.	15°–25°.
2	0.999	1.11
8	1.44	1.53
16	1.61	1.84
32	1.84	2.18
128	2.61	2.90
512	3.36	3.78
1024	3.48	4.09
2048	3.80	4.26
8192	3.93	4.20

Table LXXXIX.—Temperature Coefficients in Per Cent.

v.	0°.15.	15°–25°.
2	3.27	2.44
8	3.33	2.36
16	3.16	2.45
32	3.10	2.51
128	3.41	2.50
512	3.46	2.57
1024	3.32	2.61
2048	3.35	2.50
8192	3.36	2.39

Table XC.—Percentage Dissociation.

v.	α 0°.	α 15°.	α 25°.
2	26.1	25.9	25.9
8	36.9	36.8	36.7
16	43.6	42.7	42.9
32	50.7	49.4	49.9
128	65.5	65.8	66.4
512	82.9	83.7	84.9
1024	89.5	89.2	90.7
2048	96.8	96.8	97.7
8192	100.0	100.0	100.0

Manganese Chloride.

The strength of the solution of this salt was determined gravimetrically, the manganese being weighed as the oxide, Mn_3O_4.

Table XCI.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 10°.4.	μ_v 25°.	μ_v 35°.
2	68.14	89.64	121.3	145.0
8	84.98	113.5	156.7	188.1
16	91.79	121.9	169.0	205.1
32	97.4	130.0	181.6	221.2
128	107.0	143.8	202.5	246.7
512	114.1	154.0	216.6	264.5
1024	114.9	154.9	216.8	265.4

Table XCII.—Temperature Coefficients in Conductivity Units.

v.	0°-10°.4.	10°.4-25°.	25°-35°.
2	2.07	2.17	2.37
8	2.74	2.96	3.14
16	2.89	3.23	3.61
32	3.13	3.53	3.96
128	3.54	4.02	4.42
512	3.83	4.28	4.79
1024	3.85	4.24	4.86

Table XCIII.—Temperature Coefficients in Per Cent.

v.	0°-10°.4.	10°.4-25°.	25°-35°.
2	3.03	2.42	1.95
8	3.22	2.61	2.00
16	3.15	2.65	2.14
32	3.21	2.72	2.13
128	3.31	2.79	2.18
512	3.37	2.80	2.22
1024	3.35	2.74	2.24

Table XCIV.—Percentage Dissociation.

v.	α 0°.	α 10°.4.	α 25°.	α 35°.
2	59.3	57.9	56.0	54.6
8	74.0	73.3	72.3	70.9
16	79.0	78.7	78.0	77.3
32	84.8	83.9	83.8	83.1
128	93.1	92.8	93.4	93.0
512	99.3	99.4	99.9	99.7
1024	100.0	100.0	100.0	100.0

Manganese Nitrate.

The strength of the mother-solution was determined gravimetrically, the manganese being weighed as the oxide, Mn_3O_4.

Table XCV.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 10°.2.	μ_v 25°.	μ_v 35°.
2	66.1	85.4	116.3	138.7
8	83.1	104.1	144.3	172.5
16	85.5	111.5	154.5	185.1
32	90.5	118.8	165.0	197.9
128	98.3	129.7	182.0	219.8
512	104.8	138.4	194.6	236.2
1024	105.4	139.3	195.8	237.4

Table XCVI.—Temperature Coefficients in Conductivity Units.

v.	0°-10°.2.	10°.2-25°.	25°-35°.
2	1.89	2.09	2.24
8	2.06	2.72	2.82
16	2.55	2.90	3.06
32	2.77	3.12	3.29
128	3.07	3.53	3.78
512	3.29	3.08	4.16
1024	3.33	3.82	4.16

Table XCVII.—Temperature Coefficients in Per Cent.

v.	0°-10°.2.	10°.2-25°.	25°-35°.
2	2.86	2.45	1.93
8	2.48	2.61	1.95
16	2.98	2.60	1.98
32	3.06	2.63	1.99
128	3.12	2.72	2.08
512	3.13	2.75	2.14
1024	3.15	2.74	2.13

Table XCVIII.—Percentage Dissociation.

v.	α 0°.	α 10°.2.	α 25°.	α 35°.
2	62.7	61.3	59.4	58.4
8	78.8	74.7	73.7	72.7
16	81.1	80.0	78.9	78.0
32	85.9	85.2	84.3	83.4
128	93.3	93.1	93.0	92.6
512	99.4	99.4	99.4	99.5
1024	100.0	100.0	100.0	100.0

Cobalt Chloride.

By means of several gravimetric determinations, as cobalt sulphate, the strength of the mother-solution was ascertained. From this the other solutions were obtained by dilution. It is apparent, from the tables, that results of the same character were obtained with cobalt chloride as with the other salts.

Hydrolysis probably came into play, to some extent, in the more dilute solutions.

Table XCIX.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 7°.2.	μ_v 25°.	μ_v 35°.
2	71.77	87.16	129.5	154.9
8	87.75	107.4	161.5	195.4
16	94.08	115.3	174.2	211.3
32	100.2	122.8	186.7	226.6
128	109.6	135.1	207.1	252.1
512	116.5	143.7	221.2	270.5
1024	116.8	144.0	221.1	270.6

Table C.—Temperature Coefficients in Conductivity Units.

v.	0°-7°.2.	7°.2-25°.	25°-35°.
2	2.14	2.38	2.54
8	2.73	3.04	3.39
16	2.95	3.31	3.71
32	3.14	3.59	3.99
128	3.54	4.04	4.50
512	3.77	4.35	4.93
1024	3.78	4.33	4.95

Table CI.—Temperature Coefficients in Per Cent.

v.	0°-7°.2.	7°.2-25°.	25°-35°.
2	2.98	2.73	1.96
8	3.11	2.83	2.10
16	3.14	2.87	2.13
32	3.13	2.92	2.14
128	3.23	2.99	2.17
512	3.23	3.03	2.22
1024	3.24	3.01	2.24

Table CII.—Percentage Dissociation.

v.	α 0°.	α 7°.2.	α 25°.	α 35°.
2	61.4	60.5	58.6	57.2
8	75.1	74.6	73.0	72.2
16	80.5	80.1	78.8	78.1
32	85.8	85.3	84.4	83.7
128	93.8	93.8	93.7	93.2
512	99.7	99.8	100.0	100.0
1024	100.0	100.0	100.0	100.0

Cobalt Nitrate.

The strength of the original solution was determined gravimetrically, the cobalt being weighed as sulphate.

The salt is probably hydrolyzed, to some extent, in very dilute solutions.

Table CIII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 5°.4.	μ_v 25°.	μ_v 35°.
2	71.65	82.27	125.9	150.7
8	87.07	101.0	157.9	189.9
16	93.16	108.2	169.2	204.7
32	98.9	114.7	180.8	218.6
128	108.0	125.8	200.4	242.2
512	115.9	135.5	215.5	262.1
1024	116.1	135.4	215.3	262.0

Table CIV.—Temperature Coefficients in Conductivity Units.

v.	0°-5°.4.	5°.4-25°.	25°-35°.
2	1.97	2.23	2.48
8	2.39	2.90	3.20
16	2.79	3.11	3.55
32	2.92	3.37	3.78
128	3.30	3.81	4.18
512	3.63	4.08	4.66
1024	3.57	4.08	4.67

Table CV.—Temperature Coefficients in Per Cent.

v.	0°-5°.4.	5°.4-25°.	25°-35°.
2	2.75	2.71	1.97
8	2.74	2.87	2.03
16	2.99	2.87	2.09
32	2.95	2.94	2.09
128	3.06	3.03	2.09
512	3.13	3.01	2.16
1024	3.08	3.01	2.17

Table CVI.—Percentage Dissociation.

v.	α 0°.	α 5°.4.	α 25°.	α 35°.
2	61.7	60.8	58.5	57.5
8	75.0	74.6	73.3	72.5
16	80.2	79.9	78.6	78.1
32	85.2	84.7	84.0	83.4
128	93.0	92.9	93.1	92.4
512	99.8	100.0	100.0	100.0
1024	100.0	100.0	100.0	100.0

Nickel Chloride.

The original solution of nickel chloride was standardized electrolytically, according to the method of Smith and Exner. The salt was converted into sulphate, evaporated to dryness, the residue dissolved in ammonium sulphate and the solution treated with ammonia until strongly alkaline. The nickel was then determined electrolytically.

The salts of nickel, like those of cobalt, probably show small hydrolysis at high dilutions.

Table CVII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 6°.3.	μ_v 25°.	μ_v 35°.
2	73.07	86.49	131.7	158.0
8	89.51	106.3	164.8	198.9
16	95.79	114.4	177.4	215.3
32	102.1	122.0	190.5	231.2
128	112.0	134.7	211.6	256.8
512	119.9	144.5	227.2	276.8
1024	120.7	145.4	229.0	279.4

Table CVIII.—Temperature Coefficients in Conductivity Units.

v.	0°-6°.3.	6°.3-25°.	25°-35°.
2	2.13	2.42	2.63
8	2.67	3.13	3.41
16	2.95	3.37	3.79
32	3.16	3.66	4.07
128	3.57	4.11	4.52
512	3.90	4.42	4.96
1024	3.92	4.47	5.04

Table CIX.—Temperature Coefficients in Per Cent.

v.	0°-6°.3.	6°.3-25°.	25°-35°.
2	2.91	2.80	2.00
8	2.98	2.94	2.07
16	3.08	2.95	2.14
32	3.10	3.00	2.14
128	3.19	3.05	2.14
512	3.25	3.06	2.18
1024	3.25	3.07	2.20

Table CX.—Percentage Dissociation.

v.	α 0°.	α 6°.3.	α 25°.	α 35°.
2	60.5	59.5	57.5	56.6
8	74.2	73.1	72.0	71.2
16	79.4	78.7	77.5	77.1
32	84.6	83.9	83.1	82.7
128	92.8	92.6	92.4	91.9
512	99.3	99.4	99.2	99.1
1024	100.0	100.0	100.0	100.0

Nickel Nitrate.

The standardization of the mother-solution of nickel nitrate was carried out in the same manner as in the case of nickel chloride. The nickel was determined electrolytically, according to the method of Smith and Exner.

Table CXI.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 6°.	μ_v 25°.	μ_v 35°.
2	71.34	83.06	125.3	150.4
8	87.35	102.7	157.9	190.0
16	93.67	109.9	169.7	204.8
32	99.15	116.8	180.9	218.6
128	108.3	128.7	200.1	242.9
512	116.1	137.2	215.4	261.3
1024	115.8	137.4	214.3	260.1

Table CXII.—Temperature Coefficients in Conductivity Units.

v.	0°-6°.	6°-25°.	25°-35°.
2	1.95	2.22	2.51
8	2.56	2.91	3.21
16	2.71	3.15	3.51
32	2.94	3.37	3.77
128	3.40	3.76	4.28
512	3.52	4.12	4.59
1024	3.60	4.05	4.58

Table CXIII.—Temperature Coefficients in Per Cent.

v.	0°-6°.	6°-25°.	25°-35°.
2	2.73	2.67	2.00
8	2.93	2.83	2.03
16	2.89	2.87	2.07
32	2.97	2.89	2.08
128	3.14	2.92	2.14
512	3.03	3.00	2.13
1024	3.11	2.95	2.14

Table CXIV.—Percentage Dissociation.

v.	α 0°.	α 6°.	α 25°.	α 35°.
2	61.6	60.5	58.5	57.8
8	75.4	74.7	73.7	73.0
16	80.9	80.0	79.2	78.7
32	85.6	85.0	84.4	84.0
128	93.5	93.7	93.4	93.4
512	100.0	99.9	100.0	100.0
1024	100.0	100.0	100.0	100.0

Copper Chloride.

The exact strength of the mother-solution was obtained by several gravimetric determinations. The copper was precipitated with sodium hydroxide and weighed as cupric oxide. The solution was then diluted to 0.5 N and from this the others were obtained by dilution.

Hydrolysis comes into play here to a greater extent than with any of the previous salts. This is shown in the conductivities, which continue to increase even at the highest dilutions studied. We think that the value of μ_v at 1000 liters is not widely removed from the true value of $\mu\infty$.

Table CXV.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 13°.8.	μ_v 25°.	μ_v 35°.
2	68.95	96.36	119.8	141.3
8	87.57	127.0	158.3	189.9
16	94.82	137.0	173.5	208.6
32	101.3	147.1	187.5	226.2
128	111.5	164.5	210.1	255.6
512	118.4	175.3	224.0	273.4
1024	123.0	181.7	232.2	282.6

Table CXVI.—Temperature Coefficients in Conductivity Units.

v.	0°-13°.8.	13°.8-25°.	25°-35°.
2	1.99	2.09	2.15
8	2.86	2.79	3.16
16	3.06	3.26	3.51
32	3.32	3.61	3.87
128	3.84	4.07	4.55
512	4.12	4.35	4.94
1024	4.25	4.51	5.04

Table CXVII.—Temperature Coefficients in Per Cent.

v.	0°-13°.8.	13°.8-25°.	25°-35°.
2	2.89	2.17	1.79
8	3.26	2.20	2.00
16	3.23	2.37	2.02
32	3.28	2.45	2.06
128	3.44	2.47	2.17
512	3.48	2.48	2.20
1024	3.46	2.48	2.17

Table CXVIII.—Percentage Dissociation.

v.	α 0°.	α 13°.8.	α 25°.	α 35°.
2	56.1	53.0	51.6	50.0
8	71.2	69.9	68.2	67.2
16	77.1	75.4	74.7	73.8
32	82.4	81.0	80.7	80.0
128	90.7	90.5	90.5	90.4
512	96.3	96.5	96.5	96.7
1024	100.0	100.0	100.0	100.0

Copper Nitrate.

The solution of this salt was standardized gravimetrically, the copper being weighed as cupric oxide. Conductivity measurements were made at 5 different temperatures. The effect of temperature on conductivity, temperature coefficients and dissociation is the same as with the other salts we have considered.

The remarks in reference to hydrolysis apply here, as in the case of copper chloride.

Table CXIX.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 5°.	μ_v 15°.8.	μ_v 25°.	μ_v 35°.
2	69.38	79.17	102.5	123.3	147.1
8	86.48	99.21	130.0	156.7	188.5
16	93.0	106.7	140.2	169.4	204.0
32	99.15	113.8	150.0	181.8	219.9
128	109.0	125.5	166.5	201.9	245.0
512	117.7	136.1	180.2	218.4	266.6
1024	119.8	138.6	183.3	222.9	271.7

Table CXX.—Temperature Coefficients in Conductivity Units.

v.	0°-5°.	5°-15°.8.	15°.8-25°.	25°-35°.
2	1.96	2.16	2.26	2.38
8	2.55	2.85	2.90	3.18
16	2.74	3.10	3.17	3.46
32	2.93	3.35	3.46	3.81
128	3.30	3.80	3.85	4.31
512	3.68	4.08	4.15	4.82
1024	3.76	4.14	4.30	4.88

Table CXXI.—Temperature Coefficients in Per Cent.

v.	0°-5°.	5°-15°.8.	15°.8-25°.	25°-35°.
2	2.83	2.73	2.20	1.93
8	2.95	2.87	2.23	2.03
16	2.95	2.91	2.26	2.04
32	2.95	2.94	2.31	2.10
128	3.03	3.03	2.33	2.14
512	3.13	3.00	2.30	2.21
1024	3.14	2.99	2.35	2.19

Table CXXII—Percentage Dissociation.

v.	α 0°.	α 5°.	α 15°.8.	α 25°.	α 35°.
2	57.9	57.1	55.9	55.3	54.1
8	72.2	71.6	70.9	70.3	69.4
16	77.6	77.0	76.5	76.0	75.1
32	82.8	82.1	81.9	81.6	80.9
128	91.0	90.5	90.8	90.6	90.2
512	98.2	98.2	98.3	98.0	98.0
1024	100.0	100.0	100.0	100.0	100.0

Hydrochloric Acid.

The original solution was prepared by dissolving pure hydrochloric acid in redistilled water. By means of the hydrometer the solution was diluted to approximately 0.25 N concentration. The exact strength was then determined by diluting the original solution five times and titrating successive portions by means of a standard solution of potassium hydroxide. The potassium hydroxide solution used had been carefully standardized against sulphuric acid, which, in turn, had been standardized gravimetrically by precipitation as barium sulphate. From the data thus obtained, the mother-solution was diluted with the proper volume of water to make it exactly 0.25 N. This dilution was then checked by titrating. The other solutions were obtained by diluting the original one.

Hydrochloric acid is a very strong acid. This is shown by the fact that a 0.25 N solution is dissociated more than 90 per cent and the value of $\mu\infty$ is obtained at a volume of about 128. Table CXXIV. shows a close agreement between the values of

the molecular conductivities as found by Ostwald and Krannhals and those which we have obtained.

In Table CXXV., *the temperature coefficients in conductivity units decrease with rise in temperature.* This is true, in general, in the case of acids, while with salts the opposite is true. The effect of temperature on conductivity, percentage temperature coefficients of conductivity and dissociation is of the same general character as in the case of salts.

The temperature coefficients, in conductivity units, are very high and also the conductivities. This is due to the acid being one of the very strongest and the hydrogen ion being the swiftest of all ions.

Table CXXIII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 12°.5.	μ_v 25°.	μ_v 25°.
4	223.3	285.9	348.2	397.9
8	227.0	292.2	357.0	407.1
16	231.8	298.7	365.2	415.5
32	235.0	303.3	370.7	423.4
128	238.8	309.0	379.3	433.3
512	235.5	304.2	374.7	428.3
1024	221.5	287.7	353.4	405.3

Table CXXIV.—Comparison with the Work of Others.

	Ostwald.	Krannhals.	Calculated.
v.	μ_v 25°.	μ_v 18°.	μ_v 18°.
4	343	313	313.3
8	355	323	320.7
16	362	329	328.0
32	369	335	333.0
128	376	341	340.0

Table CXXV.—Temperature Coefficients in Conductivity Units.

v.	0°-12°.5.	12°.5-25°.	25°-35°.
4	5.01	4.98	4.97
8	5.22	5.18	5.01
16	5.35	5.32	5.03
32	5.46	5.39	5.27
128	5.62	5.62	5.40
512	5.50	5.64	5.36
1024	5.30	5.26	5.19

Table CXXVI.—Temperature Coefficient in Per Cent

v	0°-18°.	12.5°-25°.	25°-35°
4	2.24	1.74	1.43
8	2.30	1.77	1.46
16	2.31	1.78	1.48
32	2.37	1.77	1.42
128	2.35	1.82	1.42
512	2.34	1.85	1.43
1024	2.39	1.83	1.47

Table CXXVII.—Percentage Dissociation.

v	α 0°.	α 12°.5	α 25°.	α 35°
4	93.5	92.5	91.8	91.8
8	95.1	94.6	94.1	93.9
16	97.1	96.7	96.3	95.9
32	98.4	98.2	97.7	97.7
128	100.0	100.0	100.0	100.0

Nitric Acid.

The solution was prepared and standardized in the same manner as that of hydrochloric acid.

Results of the same general character were obtained with nitric acid as with hydrochloric acid. In Table CXXIX., the temperature coefficients expressed in conductivity units, decrease with rise in temperature. Like hydrochloric acid, nitric acid is also a very strong electrolyte. The value of μ_∞ is obtained at a value of about 128.

The same remarks apply to the temperature coefficients and the conductivity of nitric as to those of hydrochloric acid.

Table CXXVIII.—Molecular Conductivities.

v	μ_v 0°.	μ_v 12°.5.	μ_v 25°.	μ_v 35°.
4	222.4	284.3	344.4	390.8
8	226.9	290.5	354.4	402.7
16	231.3	296.3	362.0	411.8
32	235.4	301.7	368.7	418.6
128	238.3	305.2	376.6	429.4
512	236.7	306.0	373.9	426.9
1024	231.4	299.9	366.5	419.8

Table CXXIX.—Temperature Coefficients in Conductivity Units.

v.	0°-12°.5.	12°.5-25°.	25°-35°.
4	4.95	4.81	4.64
8	5.09	5.11	4.83
16	5.20	5.25	4.98
32	5.30	5.36	4.99
128	5.59	5.47	5.28
512	5.54	5.43	5.30
1024	5.48	5.33	5.33

Table CXXX.—Temperature Coefficients in Per Cent.

v.	0°-12°.5.	12°.5-25°.	25°-35°.
4	2.23	1.69	1.35
8	2.24	1.76	1.36
16	2.25	1.77	1.38
32	2.25	1.78	1.35
128	2.34	1.77	1.40
512	2.34	1.77	1.42
1024	2.37	1.78	1.45

Table CXXXI.—Percentage Dissociation.

v.	α 0°.	α 12°.5.	α 25°.	α 35°.
4	93.3	92.2	91.4	91.0
8	95.2	94.3	94.1	93.8
16	97.1	96.1	96.1	95.9
32	98.8	97.9	97.6	97.5
128	100.0	100.0	100.0	100.0

Sulphuric Acid.

By means of the hydrometer and Lunge's tables, a solution approximately 0.25 N was made. A portion of this was then diluted ten times and this diluted portion standardized by precipitation with barium chloride. From the data thus obtained, the mother-solution was diluted to exactly 0.25 N. This dilution was then checked by further precipitation. The comparisons, given in Table CXXXIII., between our calculated results and those obtained experimentally by Kohlrausch at 18°, are not quite as satisfactory as the comparisons with other substances.

Table CXXXII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 16°.3.	μ_v 25°.	μ_v 35°.
4	292.9	382.8	419.3	457.2
8	303.9	393.9	431.5	471.7
16	323.6	417.3	456.6	498.0
32	347.2	450.0	491.4	533.6
128	403.6	535.6	589.4	646.2
512	442.7	601.1	675.2	753.0
2048	449.2	622.4	709.9	814.4
8192	441.6	618.2	708.6	816.3

Table CXXXIII.—Comparison with the Work of Kohlrausch.

	Kohlrausch.	Calculated.
v.	μ_v 18°.	μ_v 18°.
4	379.8	389.9
16	...	425.0
20	416.8	...
32	...	458.1
40	468.6	...
128	...	546.1
200	571.0	...
333	600.2	...
512	...	615.6
2000	663.2	...
2048	...	639.5

Table CXXXIV.—Temperature Coefficients in Conductivity Units.

v.	0°-16°.3.	16°.3-25°.	25°-35°.
4	5.52	4.20	3.79
8	5.52	4.32	4.02
16	5.75	4.52	4.14
32	6.31	4.76	4.22
128	8.10	6.18	5.68
512	9.72	8.52	7.78
2048	10.63	10.06	10.45
8192	10.83	10.39	10.77

Table CXXXV.—Temperature Coefficients in Per Cent.

v.	0°-16°.3.	16°.3-25°.	25°-35°.
4	1.88	1.10	0.90
8	1.49	1.10	0.93
16	1.78	1.08	0.91
32	1.82	1.06	0.86
128	2.01	1.15	0.96
512	2.19	1.42	1.15
2048	2.37	1.62	1.47
8192	2.45	1.68	1.52

Table CXXXVI.—Percentage Dissociation.

v.	α 0°.	α 16°.3.	α 25°.	α 35°.
4	65.2	61.5	59.1	56.1
8	67.7	63.3	60.8	57.9
16	72.0	67.0	64.3	61.2
32	77.3	72.3	69.2	65.5
128	89.8	86.1	83.0	79.3
512	98.6	96.6	95.1	92.5
2048	100.0	100.0	100.0	100.0

Oxalic Acid.

The sample of oxalic acid used was purified by repeated crystallizations and was then thoroughly air-dried. The mother-solution was made up by direct weighing, the others being obtained by dilution. As is shown by the values of the molecular conductivities given in Table CXXXVII., oxalic acid is much weaker than the other acids we have considered. With it, as with other acids and salts which we have studied, the effect of rise in temperature from 0° to 35° is to decrease the percentage temperature coefficients of conductivity.

Table CXXXVII.—Molecular Conductivities.

v.	μ_v 0°.	μ_v 11°.8.	μ_v 25°.	μ_v 35°.
2	79.43	100.1	123.1	135.6
8	123.5	156.3	189.8	212.3
16	147.2	186.4	227.1	255.2
32	169.8	215.1	262.3	295.8
128	203.8	260.2	318.9	361.1
512	223.7	285.3	349.9	397.1
2048	240.2	307.4	375.6	428.1
8192	265.0	334.0	412.0	466.0

Table CXXXVIII.—Temperature Coefficients in Conductivity Units.

v.	0°-11°.8.	11°.8-25°.	25°-35°.
2	1.75	1.74	1.25
8	2.77	2.54	2.25
16	3.32	3.08	2.81
32	3.84	3.58	3.35
128	4.78	4.45	4.22
512	5.22	4.89	4.72
2048	5.69	5.17	5.25
8192	5.85	5.91	5.40

Table CXXXIX.—Temperature Coefficients in Per Cent.

v.	0°-11°.8.	11°.8-25°.	25°-35°.
2	2.20	1.74	1.02
8	2.24	1.63	1.19
16	2.26	1.65	1.24
32	2.26	1.67	1.28
128	2.35	1.71	1.32
512	2.33	1.71	1.35
2048	2.36	1.68	1.40
8192	2.21	1.77	1.31

Discussion of Results.

It was pointed out in the historical review of this subject, that up to the present no final conclusions had been reached as to the exact effect of temperature on dissociation, over the range of temperature from 0° to 35°. A number of investigators have made conductivity measurements at different temperatures, but concordant results have not been obtained by those who have worked in this field. Moreover, no one has studied the exact temperature effect for any very large number of substances having different degrees of dissociation.

We have studied, in all, 32 substances, inorganic and organic, with very different degrees of dissociation. Without a single exception, results of the same character have been obtained with every one of them. The percentage dissociation and the percentage temperature coefficients of conductivity decrease with rise in temperature. The effect of temperature on

the temperature coefficients of conductivity, expressed in conductivity units, is, however, different in the case of salts from that in the case of acids. This fact has been clearly demonstrated. With salts, the temperature coefficients of conductivity, expressed in conductivity units, increase with rise in temperature, while, in the case of acids, they decrease with rise in temperature.

A number of tables have been incorporated, showing a comparison of our results with those of others. As we have seen, the agreement between the two sets of values has been, in general, satisfactory.

Sufficient evidence has, undoubtedly, been obtained in this investigation to justify the conclusion that the percentage dissociation and the percentage temperature coefficients of conductivity decrease with rise in temperature, from 0° to 35°.

From the data presented, it is apparent that the tables representing the percentage temperature coefficients of conductivity and percentage dissociation run parallel. The percentage temperature coefficients of conductivity and the percentage dissociation decrease with rise in temperature. These facts are interesting in the light of certain hypotheses, which have been advanced in recent years.

Dutoit and Aston[1] have suggested the following relation; that only in those solvents which are polymerized or associated, do dissolved substances conduct the current. That is, the more associated a solvent the greater its dissociating power. Dutoit and Friderich[2] have also shown this relation to be true in a number of cases.

Ramsay and Shields[3] proved that in many liquids the molecules are not the simplest possible, but are aggregates of these simplest molecules, having various degrees of complexity; that is, the liquid molecules are polymerized aggregates of the simplest molecules. Water, one of the strongest dissociants, has a high degree of association. At 0° the molecule is $(H_2O)_4$. As the temperature is raised, the association becomes less, as Ramsay and Shields showed by the following data:

[1] Compt. rend., **125**, 540 (1897).
[2] Bull. Soc. Chim., [3], **19**, 321 (1898).
[3] J. Chem. Soc., **63**, 1089 (1893).

	0°.	10°.	20°.	30°.	40°.
Association factor x	4	3.81	3.68	3.44	3.18

It is obvious that, as the temperature of an aqueous solution of an electrolyte is increased, the ionic mobility is increased. At the same time the solvent water is becoming less and less associated with rise in temperature. As the association of the solvent decreases its dissociating power becomes less, according to the hypothesis of Dutoit and Aston. Thus we have two conditions affecting conductivity with rise in temperature, and they work counter to each other. The ions move faster with rise in temperature, increasing the conductivity. The association of the solvent becomes less with rise in temperature and, consequently, its dissociating power becomes less. This diminishes the conductivity. These facts are brought out very clearly by the data presented.

We have seen that conductivity increases with rise in temperature, the percentage of increase in conductivity per degree, decreases with rise in temperature, and the dissociation decreases with rise in temperature. In brief, when the temperature of an aqueous solution of an electrolyte is raised, the association of the water is decreased. The effect of this is to diminish its dissociating power and this, in turn, decreases the dissociation of the dissolved substance. Dissociation, then, is driven back by rise in temperature. The conductivity of a solution is conditioned by the number of ions present and by their velocity. The effect of decrease in dissociation with rise in temperature is to reduce the amount of conducting substance, or the number of ions in the solution. Consequently, although conductivity increases with rise in temperature, due to increase in ionic mobility, the percentage of increase in conductivity, per degree, should decrease ; otherwise, the conductivity-temperature curve would not reach a maximum with rise in temperature. This fact is clearly brought out and is in harmony with previous work at high temperatures, which shows a maximum in the conductivity curve with rise in temperature. It is also in harmony with the idea advanced by Bousfield and Lowry, in their curve representing the effect of

temperature on the conductivity of a composite electrolyte. The curve reaches a maximum and then drops.

The results presented in these tables are interesting in connection with the hypothesis of Thompson and Nernst. J. J. Thompson[1] and, a little later, Nernst[2] pointed out that, if the forces which hold the atoms in the molecule are of an electrical nature, those solvents that have the highest dielectric constants should have the greatest dissociating power.

The work which has, thus far, been done shows that this is, in general, true.[3] O. U. Vonwiller[4] studied the dielectric constant of water, at various temperatures ranging from 0° to 28° and found that, with rise in temperature, the dielectric constant of water gradually decreased. If the dielectric constant of a solvent decreases with rise in temperature, then, according to the hypothesis of Thompson and Nernst, its dissociating power should decrease with rise in temperature. Consequently, the dissociation of the dissolved substance should decrease as the temperature rises. Fact and theory are in accord. We have shown that there is a decrease in dissociation with rise in temperature. The work of Vonwiller is, then, a connecting link between the Thompson-Nernst hypothesis and the experimental results obtained in this investigation. A number of electrolytes have been examined and, in each case, results of the same general character have been obtained.

It thus seems to be proved experimentally, for a large number of substances, what a few investigators have made probable for a few substances, over a wide range of temperature. Our results are in harmony with previous work at high temperatures, showing a maximum in the conductivity-temperature curve with rise in temperature, and also with the hypothesis of Bousfield and Lowry, in their curve representing the effect of temperature on the conductivity of a composite electrolyte. That there is a satisfactory agreement between the results of our experiments, the hypothesis of Dutoit and Aston and the work of Ramsay and Shields has been

[1] Phil. Mag., **36**, 320 (1894).
[2] Z. physik. Chem., **13**, 531 (1894).
[3] Jones and Carroll : Am. Chem. J., **32**, 521 (1904).
[4] Phil. Mag., [6], **7**, 655 (1904).

clearly demonstrated. We have also referred to the results of Vonwiller, and pointed out the fact that the Thompson-Nernst hypothesis holds admirably, in aqueous solutions, over a considerable range of temperature. When the temperature of an aqueous solution of an electrolyte is increased from 0° to 35°, the results expressed in tabular form are as follows:

With rise in temperature from 0° to 35°.	Association of solvent decreases.
	Dielectric constant of solvent decreases.
	Viscosity of solvent decreases.
	Dissociation of dissolved substance decreases.
	Percentage temperature coefficients of conductivity decrease.
	Ionic mobility increases.

SUMMARY AND CONCLUSIONS.

When the temperature of an aqueous solution of an electrolyte is raised from 0° to 35°, the effect of rise in temperature on conductivity, dissociation and on the temperature coefficient of conductivity has been determined and the following relation shown to exist:

Effect of Rise in Temperature from 0° to 35°.

1. A large increase in conductivity, due to increase in ionic mobility.

2. A small decrease in dissociation, in accordance with the law of Dutoit and Aston, connecting association of solvent and dissociation of dissolved substance, and in accordance with the results of Ramsay and Shields, showing a decrease in the association of water with rise in temperature.

3. From the results of Vonwiller, showing a decrease in the dielectric constant of water with rise in temperature, and the Thompson-Nernst hypothesis, connecting the dissociating power of a solvent with its dielectric constant, we should expect a decrease in dissociation with rise in temperature. This

has been demonstrated experimentally over a considerable range of temperature.

4. The temperature coefficients of conductivity, expressed in percentage of conductivity units, decrease with rise in temperature, and this fact is in accordance with the maximum in the conductivity-temperature curve of an electrolyte, as pointed out by Bousfield and Lowry, and with the work of former investigators at high temperatures.

5. The temperature coefficients of conductivity, expressed in conductivity units, in the case of salts increase with rise in temperature, while with acids they decrease with rise in temperature.

BIOGRAPHY.

The author of this dissertation, Augustus Price West, was born in Baltimore, Maryland, on February 6th, 1878. His preparatory training was received at first in the public schools of Baltimore and later under the guidance of private tutors. He entered the Johns Hopkins University in the fall of 1898 and was graduated in June, 1901, with the degree of Bachelor of Arts. The following autumn he entered the graduate department of the Johns Hopkins University as a student in chemistry, with physical chemistry and mineralogy as subordinate subjects.